Crimson Publishers
Wings to the Research

Mini Review

Subterranean Biodiversity in Cenotes in Mexico

Luis M Mejía Ortíz[1,2]* and Germán Yáñez[2]

[1]Biospeleology and Carcinology Lab, University Academic Unit Cozumel Quintana Roo, Mexico

[2]Speleological Circle of Mayab, Mexico

ISSN: 2770-6745

Abstract

The background of the subterranean biodiversity is showed, specifically in one of the areas most visited by tourist in the world, Yucatan Peninsula. In there exist specialized species that never has been recorder outside, the biodiversity in the aquatic ecosystems record included fishes, crustaceans, echinoderms sponge with spend all they life into the cave and it is showed a generalized classification of cenotes, energy sources, adaptations and risk to this biodiversity due the increase of the anthropogenic pressured that human population did on these environments, and end with a reflection on the future of these ecosystems and their diversity.

***Corresponding author:** Luis M Mejía Ortíz, Biospeleology and Carcinology Lab, Sustainable Development Division Universidad Autónoma del Estado de Quintana Roo Campus Cozumel, Mexico

Submission: January 25, 2024
Published: February 06, 2024

Volume 4 - Issue 3

How to cite this article: Luis M Mejía Ortíz* and Germán Yáñez. Subterranean Biodiversity in Cenotes in Mexico. Biodiversity Online J. 4(3). BOJ. 000590. 2024.
DOI: 10.31031/BOJ.2024.04.000590

Introduction

Thousands of people live and travel through one of the richest natural and cultural areas of Mexico, the Yucatan Peninsula in Mexico, the site where the Mayan culture flourished and where there is still much evidence of its rise and decline. But although it is one of the areas with a high influx of visitors from all over the world, the question is Do they have any idea of the hidden biodiversity that exists in the underground world under their feet? In the Yucatan Peninsula, the water needs of human populations are met through the use of the largest underground aquifer in the country, which has been accessible since pre-Hispanic times through the cenotes that the Mayans have called "d'zonot". and that throughout history have been valued by the Mayan culture as the entrances to the underworld. Where, thanks to the archaeological remains, it has been possible to identify its value in the different ceremonies, although underground paths are still present in those systems that were used in funerary rites [1]. This has been possible due to the karst origin of the platform that is known today as the Yucatan Peninsula and that has emerged gradually in recent geological periods, but which in turn has been flooded as a result of the glaciations to which it has been exposed, which has allowed a geomorphological diversity in its interior and even in the entrances to the underground world that range from small cracks in the rock to large and deep sinkholes of several tens of meters as can be found today [2]. The cenotes have been classified according to their shape, pitcher, closed, open, watery or cylindrical, also if they have a terrestrial space or are completely flooded and if they have the interaction of layers of freshwater with layers of marine or brackish water inside. There are cenotes with significant water flows that drain towards the coast or some are currently known that contain waters with little flow and exchange and therefore present water that has been in a seasonal state for a long time at great depths (Figure 1). The Yucatan Peninsula is not a uniform calcareous plate, as it presents fractures or geological faults as well as different moments of outcrop, which in turn has allowed the establishment of different soils, as well as some small elevations up to 300 meters high, which entails to have six physiographic zones identified in conjunction with water flows and where more than 4,500 cenotes, grottos and caverns have been recorded, many of them interconnected forming large underground rivers such as Ox Bel Ha and Sac Actun on the coasts of the Mexican Caribbean [3], but also important provinces such as the Ring of Cenotes that surround the city of Mérida in Yucatán and that provides water to said community. The

human population in the Peninsula is concentrated mainly in the cities of Mérida, Progreso, Valladolid, Campeche, Cancún, Playa del Carmen, Tulum and Chetumal. Although, there are other cities and hundreds of smaller towns, many of them associated with cenotes or caves that even carry in their name a connotation of their existence (Dzonotchel, Dzonot Carretero, Dzonot Ake, Dzonot Tigre). Likewise, there are many Mayan archaeological cities related to the underground environment for various rites and ceremonies but that today are part of the cultural heritage that the region has and that are cared for and preserved under the responsibility of the Mexican state, as is the case of Chichen. Itza, Uxmal, Tulum, Coba among others. Currently this region is one of the most visited in the world with around 35 million visitors a year, as it has paradisiacal beaches, underwater natural beauties, a preserved tropical jungle with emblematic organisms such as Jaguar, Spider Monkey, Manatees, Whale Shark, Crocodiles, Macaws but also with a Mayan cultural wealth, having among its archaeological sites Uxmal, Calakmul or Chichen Itza, one of the seven wonders of the modern world. In addition to a cultural wealth in terms of food, dances, Mayan performances, which tourists want to experience. Considering the above, there has been a close relationship between humans (locals or visitors) with the underground world of the Peninsula. However, at a general level there is little understanding of the underground aquifer but especially of all those millions of visitors, very few understand that there is a biodiversity hidden under their feet with a high degree of specialization and that everything done outside has an impact on these systems since none is completely isolated.

Figure 1: Cenotes a window to subterranean world. Cenote Aerolito Isla de Cozumel, Quintana Roo, Mexico.

Subterranean Ecosystems

We will begin by understanding that in the underground ecosystem there are two major environments, which are: terrestrial, for those dry or semi-dry caves or grottoes that allow the establishment of various insects, spiders, reptiles, mammals and birds and secondly the aquatic, which are those flooded systems called cenotes or some caves with natural bodies of water and which in turn can be subdivided into:

a) Completely freshwater aquatic environments that exist throughout the length and breadth of the Yucatan Peninsula with zero salinity conditions, dissolved oxygen values that are incorporated by diffusion in small quantities depending on the distance of the aquatic reservoir from the entrance and with average temperatures of 23ºC.

b) Marine-brackish environments, which are mainly associated with the coasts, are systems of horizontal caverns that present marine water inflow and that, derived from the interaction of freshwater (which is in a constant flow towards the sea), have mainly an area of mixing and in the upper part of the body of water it presents values of 10 to 24 partial salinity units (UPS), reaching only in the deepest parts values of marine waters (35-36 UPS) without marked stratification and with very similar values in the superficial and deep part of temperature and dissolved oxygen product of the mixing zone they present.

c) Anchihaline environments, which are those that have a well-defined stratification with freshwater values in the superficial layer, a zone of mixing with seawater called halocline and a lens of seawater that may be present right in its proximity to the bottom or it can be found from 1 to approximately 45 meters deep, in these systems the temperature and dissolved oxygen conditions are very different between the two layers of water, decreasing especially for oxygen until reaching levels of anoxia, which together with the presence of sulfuric acid (produced by the decomposition of organic matter that is dragged from the jungle but that at these depths and derived from the low amount of oxygen decomposes slowly) further produces anoxic layers at greater depths (Figure 2).

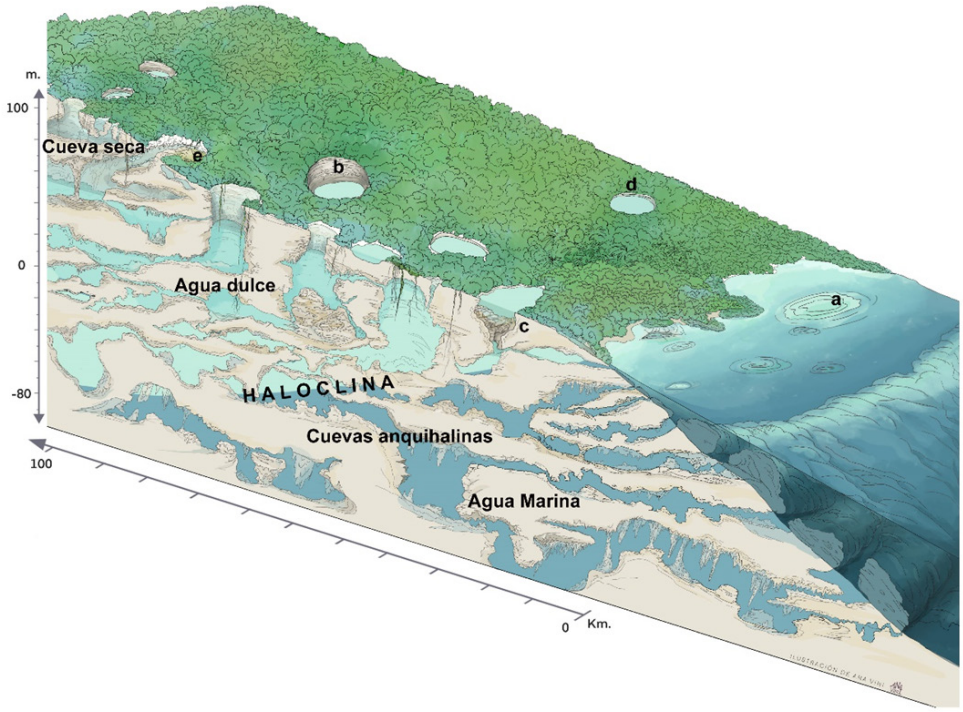

Figure 2: Schematic representation of the subterranean systems in Yucatán Peninsula.
a) Freshwater outflow in the sea. b) Pitcher cenote. c) Aguada. d) Cylindrical cenote. e) Closed with wall collapses.

Energy Sources

In these terrestrial or aquatic environments there is a biodiversity that subsists thanks to the contribution of two sources of energy, a) the allochthonous (external) generally represented by contributions of plant matter that is derived from temporary hydrological pulses (rains or hydro-meteorological phenomena such as hurricanes) but also by transport through a biological element such as bats, of which in the Peninsula it has been documented by different researchers that there are more than 60 species, highlighting *Artibeus jamaicencis, Mormoops megalophylla, Pteronotus parnellii, Pteronotus dauyi, Pteronotus personatus, Natalus stramineus, and Myotis keaysi* [4]. In addition to the fact that some animals sporadically enter the underground systems in search of shelter and food and when they do not find the exit, they perish, providing their own body as food for the organisms that permanently exist in the caves and b) the native organisms that are represented by those chemosynthetic organisms (mainly bacteria) that use sulfur sources to produce energy, especially in anchihaline systems, and which have been registered as an alternative for maintaining biological diversity independently of the outside [5]. All of the above allows life in underground environments with extraordinary evolutionary processes, since an important element in all of them is the absence of light, which produces a series of adaptations first in the organisms themselves but then various strategies for their ecological success. in such environments.

Biological Diversity

Terrestrial and aquatic organisms have been classified according to their time od live in underground environments worldwide, and in the Yucatan Peninsula there are representatives that live permanently in caves, grottoes and cenotes, which are called troglobitics (terrestrial) or stygobitic (aquatic) and that normally present very advanced degrees of adaptation. There are also those that carry out part of their life in both systems (surface and hypogeal) either due to feeding, reproduction, shelter and protection habits, which are called *troglophiles* (terrestrial) or stygophiles (aquatic), which may present some adaptations or some degree of change and finally there are other organisms that are rather sporadic and not very frequent without any adaptation to life in caves and which are called trogloxenes (terrestrial) or stigoxenes (aquatic) (Figure 3). The organisms that we can find on the Yucatan Peninsula thanks to the work of researchers from different parts of the world are species of crustaceans, fish, echinoderms and sponges, such as organisms that can be found with varying degrees of adaptation, among which stands out in the freshwater environment Creaseriella anops (aquatic mealybug), *Rhamdia guatemalensis* (catfish) *Typhlias pearsei* (White lady) *Ophisternon infernale* (Blind eel) Creaseria morleyi, Typhlatya mitchelli, Typhlatya pearsei (Shrimp), *Antromysis cenotensis* (mysidacean). while, in the anchihaline environment we can find echinoderms such as *Copidaster cavernicola*, *Ophionereis commutabilis*, sponges such as *Calyx maya*, *Haliclona stygobia*, *Haliclona chankanaabilis*, *Neosiphonia microtriaenaea*, *Svenzea germanyanezi*, *Diplastrella cozumella*, various types of endemic shrimp such as *Barbouria cubensis*, *Agostocaris bozanici*, *Agostocaris zabaletai*, *Anchialocaris paulini*, *Procaris mexicana*, *Parhippolyte stereri*, *Yagerocaris cozumel*, there are also the most primitive living crustaceans, *Xibalbanus tulumensis*, *Xibalbanus cozumelensis* and *Xibalbanus fuchscockborni*, various species of isopods and amphipods including: *Metacirolana mayana*, *Mayaweckelia cernua* [6-9].

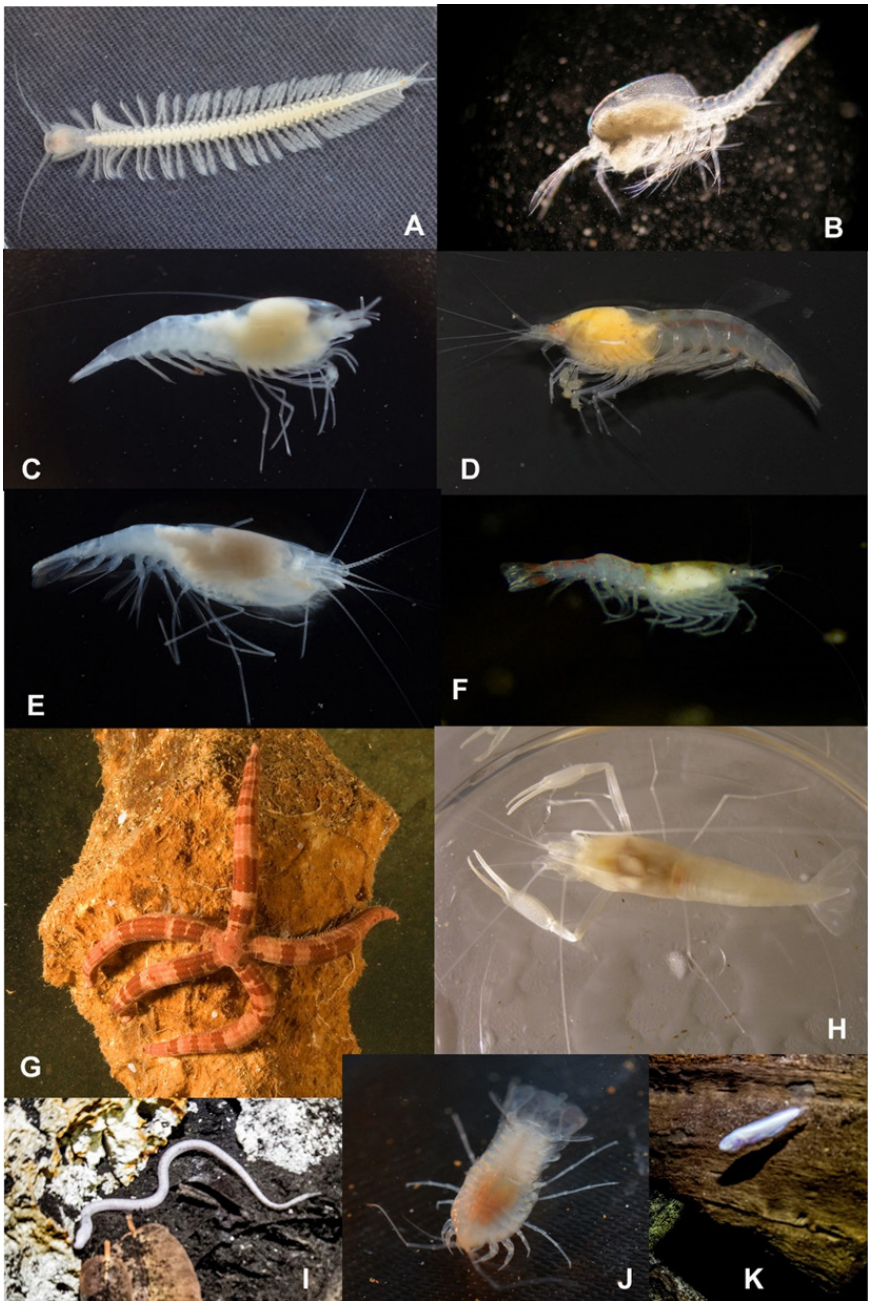

Figure 3: Biological diversity in the subterranean systems from Yucatan Peninsula. A) *Xibalbanus tulumensis* B) *Tulumella* unidens C) *Agostocaris* zabaletai D) Typhlatya sp E) *Anchialocaris* paulini F) Procaris mexicana G) Copidaster cavernicola H) Creaseria morleyi I) *Opisternon infernale* (courtesy by Juan Carmona), J) Metacirolana mayana and K) Ogilbia pearsei (courtesy by Juan Carmona).

Adaptations and Strategies to Cave Life

Regarding adaptations, there are various proposals about their origin, such as mutational changes in specific genes, but they are also attributed to the colonization time that organisms have spent living in these environments. There are progressive adaptations that we have documented in various organisms. such as:

a) Enlargement of the ambulatory and sensory appendages

b) Increase of setae in the sensory appendages

c) Development of structures specialized in lipid storage

d) Greater efficiency in feeding activity

e) Decrease in larval stages and greater parental care

f) Development of setae in the apical areas of the eyestalk of crustaceans.

While regressive adaptations are:

a) Reduction or loss of the eye

b) Disorder in the internal visual structures of the eyes

c) Decrease in pigments

d) Decrease in the rate of oxygen consumption [10,11].

Likewise, organisms, in order to survive in conditions of low energy and low abundance that allow them to even guarantee their reproduction and at the same time consider themselves ecologically successful, have developed strategies such as symbiosis between bacteria and some crustaceans, especially those that live in hypoxic areas. of the anchihaline environments where the bacteria have been recorded housed internally in the gills associated with the mitochondria, carrying out chemosynthesis to use the sulfur compounds that are dissolved in the environment and leaving the small amount of dissolved oxygen free so that the different crustaceans survive as our findings in crustaceans have shown [12,13]. On the other hand, fish have developed their navigation system more efficiently because their midline as well as their sensory organs have increased (depending on where they are distributed, since the same species can present them as long as it is in the cave). to be able to locate food, conspecifics to reproduce and predators. In the Yucatan Peninsula there are some caves in which the holes that have formed in the ceilings allow access to snakes such as the spotted mousetrap (*Elaphe flaviruta phaescens*), which feed on bats that respond to light pulses from their circadian cycle that enhance their activity at night and force them to go out to feed [14].

Risks

Given the increase in the local human population in the region, combined with a greater number of visitors from all over the planet, anthropogenic pressures towards the underground aquifer have increased. Firstly, due to the use of water resources which implies the possible salinization of the aquifer but secondly also due to the amount of solid and dissolved waste and which in some cases involves heavy metals or other elements with more negative reactions. What all of this is currently causing is that the largest aquifer, which in other times was the most conserved in the country, is now at risk. This is without taking into account all the changes in the territory of the tropical forest derived from the increase in tourist and mobility infrastructure as well as the establishment of new factories of different kinds (but highlighting the brewery and pig farms) throughout the Peninsula that are motivating that there will soon be a shortage of water resources but also a silent impact on the ecosystems that we have addressed and consequently, in the face of these changes, the fauna so specialized to survive in them will have the status of threatened species or at risk of extinction. Therefore, it is imperative to recognize that all the knowledge that the different groups of researchers have produced around each topic that these ecosystems involve has allowed us to identify that these ecosystems are fragile, with a super-specialized fauna living in unique environmental conditions that allow ecological processes. unique physiological and biochemical characteristics, and that present perfectly delineated symbioses to survive. Likewise, a high risk of becoming vulnerable ecosystems has also been identified, which must be addressed through management strategies for these underground environments and even establishing protected natural areas each time with the aim of caring for various flagship species, which could help a greater understanding for conservation. But above all, it could help each of the visitors and inhabitants of this region of the planet know what lives in these karst environments under their feet.

Acknowledgements

The authors given thanks to Ana Vini to Schematic drawing of cenotes, also to all cave divers that help in the different projects supported by CONACYT, SEP and UQroo.

Conflict of interest

The authors have not conflict of interest.

Rererences

1. Veni G (1990) Maya Utilization of kars groundwater resources. Environmental Geology Water Science 16(1): 63-66.
2. López RE (1973) Geological study of the yucatan Peninsula, Mexico. Geól Petrol 35: 24-76.
3. Mejía OLM, Sprouse P, Tejeda MJC, Valladarez J, Frausto MO, et al. (2021) Tropical subterranean ecosystems in Mexico, guatemala and belize: A review of aquatic biodiversity and their ecological aspects.
4. Mc Swney GMC (2010) Bats, biodiversity and human development in yucatán. p. 496.
5. Suárez MP, Remes RCA, Márquez VNA, Falcón LI, García MJQ, et al. (2022) Changes in the sediment microbial community structure of coastal and inland sinkholes of a karst ecosystem from the Yucatan Peninsula. Sci Rep 12(1): 1110.
6. Alvarez F, Iliffe TM, Benitez S, Brankovits D, Villalobos JL (2015) New records of anchialine fauna from the Yucatan Peninsula Mexico. Checklist 11(1): 1505.
7. Gómez P & F Calderón-Gutiérrez (2020) Anchialine cave-dwelling sponge fauna (Porifera) from La Quebrada, Mexico, with the description of the first mexican stygobiont sponges. Zootaxa 4803(1): 125-151.
8. Mejía OLM (2019) Crustacea, encyclopedia of caves. London.
9. Mejía OLM (2019) Cave crustacean decapods from Mexico.
10. Mejía OLM (2005) Adaptations to cave life in decapods from Oaxaca. p. 170.
11. Mejía OLM, López MM, Pakes J, Hartnoll RG, Zarza GE (2013) Morphological adaptations to anchialine environments in species of five shrimp families (*Barbouria yanezi*, *Agostocaris bozanici*, *Procaris mexicana Calliasmata nohochi* and *Typhlatya pearsei*). Crustaceana 86(5): 578-593.
12. Pakes JM, Weiss AK, Mejía OLM (2014) Arthropods host intracellular chemosynthetic symbionts, too: Cave study reveals an unusual form of symbiosis. Journal of Crustacean Biology 34(3): 334-341.
13. Pakes JM, Mejía OLM (2014) Chemosynthetic ectosymbiosis reported in the predatory anchialine cave endemic, Xibalbanus tulumensis (Yager, 1987) (Remipedia). Crustaceana 87(14): 1657-1667.
14. Bayona MA, Sánchez CJ (2007) Kantemó project: The cave of hanging snakes. Biodiversitas 73: 1-7.